REPORT OF SURVEY CONDUCTED AT

JLG INDUSTRIES, INC.

McCONNELLSBURG, PA

NOVEMBER 1995

Best Manufacturing Practices

CENTER OF EXCELLENCE FOR BEST MANUFACTURING PRACTICES
College Park, Maryland

Foreword

This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective towards this goal is simple: to identify best practices, document them, and then encourage industry and Government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management— areas highlighted in the Department of Defense's 4245-7.M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource to help companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to avoid costly and time-consuming duplication of what others have already tried and learned from.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at JLG Industries, Inc., conducted during the week of November 13, 1995. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from government, industry, and academia throughout the U.S. and Canada *so the knowledge can be shared.* BMP also distributes this information through several interactive services including CD-ROMs, BMPnet, and a World Wide Web homepage located on Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

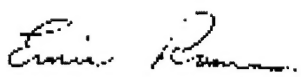
JLG Industries, Inc. is a leading manufacturer, distributor, and international marketer of mobile elevating work platforms and truck-mounted material handling equipment. Principal customers include independent distributors who market JLG products to a wider customer base. This customer base includes users in industrial, commercial, institutional and construction markets. The company supports 2,263 employees at its facilities that include McConnellsburg, Fort Littleton, Bedford, and York, Pennsylvania, as well as sales and service facilities in Scotland and Australia. JLG has achieved net sales growth of 285% since 1991 and maintains a goal of $1B in net sales by the year 2000 from the current level of $269M.

This survey presented the BMP program a unique look at a company that is growing at a pace of 50 employees per month. This growth reflects JLG's commitment to achieve world-class manufacturing status. Since 1991, the company has aggressively pursued operations goals encompassing training and education, employee involvement, advanced manufacturing resource planning and techniques, supplier partnerships, and quality improvement.

To continue increasing its share of the domestic market and to expand its international market penetration, JLG became ISO 9001 certified at the McConnellsburg site. Supported by a strong, top-level leadership, the company is striving to reach its goal of world-class manufacturing.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on JLG Industries, Inc. expands BMP's contribution toward its goal of a stronger, more competitive, and more globally-minded American industrial program.

I encourage your participation and use of this unique resource.



Ernie Renner
Director, Best Manufacturing Practices

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Report Summary

Background

JLG Industries, Inc. is a leading manufacturer, distributor, and international marketer of mobile elevating work platforms and truck-mounted material handling equipment. Principal customers include independent distributors who market JLG products to a wider customer base. This customer base includes users in industrial, commercial, institutional and construction markets. The company supports 2,263 employees at facilities that include McConnellsburg, Fort Littleton, Bedford, and York, Pennsylvania, as well as sales and service facilities in Scotland and Australia.

Co-founded in 1969 by John L. Grove and Paul K. Shockey, JLG's original prototype – an aerial work platform – embodied many basic mechanical, electrical, and hydraulic concepts still in use today. Since 1990, the company has acquired U.S. Truck Cranes, Inc. and the Alumaloft Division of the Equipment Company of America, providing the opportunity for market expansion into other areas of the crane and access business. Today, as the world's largest manufacturer of aerial work platforms and a leading producer of hydraulic truck cranes and unloaders, JLG continues to pursue innovation in equipment design and excellence in manufacturing and service.

This survey presented the Best Manufacturing Practices (BMP) program a unique look at a company that – in the midst of other industries' downsizing – is actually *growing* at a pace of 50 employees per month. This growth reflected JLG's commitment to achieve world-class manufacturing status. Since 1991, the company has aggressively pursued six main operations goals including enhancing training and education, increasing employee involvement, implementing advanced manufacturing resource planning, developing supplier partnerships, installing advanced manufacturing techniques, and executing a comprehensive quality improvement program. To continue increasing its share of the domestic market and to expand its international market penetration, JLG became ISO 9001 certified at the McConnellsburg site. The remaining Pennsylvania sites will be pursuing ISO 9000 registration in 1996.

Supported by a strong, top-level leadership, the company will reach its goal of world-class manufacturing. With a growing workforce and emphasis on quality, JLG has achieved net sales growth of 285% since 1991 and maintains a goal of $1B in net sales by the year 2000 from the current level of $269M.

The BMP survey team found the following practices to be among the best in industry and Government.

Best Practices

The BMP survey team identified the following best practices at JLG:

Information

The following information items were highlighted during the BMP survey at JLG:

Activity Point of Contact

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Section 2

Best Practices

Design/Test

IPD/Three-Dimensional Solid Modeling

JLG Industries, Inc. has developed its computer-aided design solid modeling capabilities by using software programs to evaluate designs prior to physical prototyping. Previously, JLG developed the design in two dimensions and verified the strength of structural components and machine stability by hand. Changes were then made based on those hand calculations. Prototype testing was performed in strain measurement, pressure measurement, and cycle test. If any test result was unacceptable, modifications were made on the prototype. Only then was the design approved for production.

Three-dimensional models are now entered in a database to allow analysis of any part or assembly without recreating a particular view. Properties of the model are analyzed with SDRC, ADAMS, and RASNA software. The SDRC software allows three-dimensional modeling, tolerance checks, assembly interference review, kinematic analysis, and finite element analysis, among other capabilities. ADAMS provides for kinematic and dynamic analysis. Loads at different pin joints, tire forces, and other dynamic forces at the joints due to steering, oscillating axle, rough terrain, and boom deployment can be performed on the machines. RASNA software facilitates insight into the structural integrity of beams, shells, solids, and associated buckling. SDRC and RASNA software both allow analysis of critical structural members of the machine.

With this engineering approach, stress, failure analysis, and machine stability can be observed prior to building the prototype, thereby eliminating expensive delays. Additional benefits include observing the computer-displayed ergonomics and basket movement effects in the design phase. JLG Industries, Inc. has seen a reduction in the number of prototypes, less time to market with a new product, reduced testing time, and delivery of more reliable products to the customer.

Reliability Program

JLG applies reliability techniques borrowed from the aerospace and automotive industry to enhance design improvements at the most effective period in the product's life cycle. Using these techniques, JLG evaluates the design from the customer's point of view and provides suppliers with early feedback regarding component performance. JLG tracks the mean time between failure of products, performs a failure mode effect criticality analysis (FMECA) of all designs, uses a failure reporting and corrective action system, tracks utilization (equivalent to operational availability), maintains quality costs, and has a reliability integrated design program.

The FMECA is performed during the concept phase to evaluate a proposed design. A design FMECA is then used to evaluate the design, and a process FMECA helps evaluate manufacturing flow. The failure reporting and corrective action program was implemented to provide design inputs during the feasibility and design phases. Statistical analysis and reporting is also applied to evaluate machine reliability and quality. Preliminary testability results based on customer usage is provided through the failure reporting and corrective action program.

While failure analysis is performed in-house, independent evaluation is performed during all phases. The cost of quality evaluation uses warranty and customer return information to evaluate the product life cycle costs. A repair parts usage and machine performance tracking system facilitates evaluation of the life cycle consumption. Failure analysis is performed on current products. The utilization program monitors product use to determine availability and reliability. The reliability integrated design includes a proactive working relationship with suppliers and distributors. Reliability management is performed on new components, long lead items, and others. Reliability allocation and early assessments identify any potential issues. In-house, field, and laboratory testing is performed during the various stages to ensure product capability.

This reliability program at JLG has resulted in enhanced product designs and satisfied customers. The designs also are less costly to produce.

Production/Facilities

Continuous Flow Manufacturing

JLG applied a continuous flow manufacturing (CFM) approach to achieve a continuous, balanced, and flexible flow of material/components/subassemblies to balance its work cells and final assembly lines, significantly reducing its manufacturing lead time.

By 1991, the company had grown and developed into a world leader in aerial work platform production. However,

manufacturing costs were rising, there was poor efficiency and material flow, and lead times on customer orders was extensive. Cross-functional teams were organized to analyze the flow and manufacturing processes on final assembly lines. Lift assembly lines were consolidated into three lines by product family, and work cells were developed to feed these assembly lines.

In 1992, the focus was redirected to analyze up-stream operations. A steering team, organized to develop goals and objectives, established policies and procedures to ensure all personnel were working in the same direction. Company-wide teams were developed to plan and implement physical layout changes. All CFM problems were resolved when highlighted by teams. A facilitator was assigned the role of being the champion for CFM and its integration in the manufacturing process. Pilot areas were developed to prove out changes, and the changes were integrated throughout manufacturing. Pull and Kanban systems were implemented, supplier partnerships were developed, and rate-based scheduling was introduced.

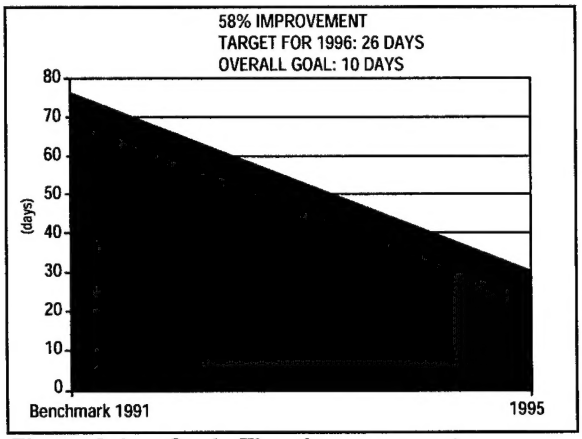


Figure 2-1. Cycle Time Improvements

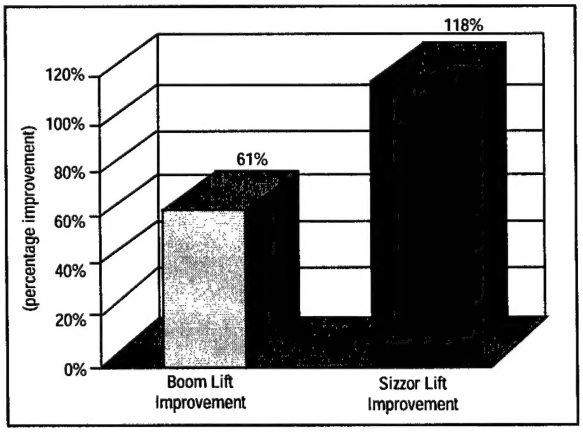


Figure 2-2. Improvement in World Wide Market Share (1991 through 1995)

CFM supported reduction of the manufacturing lead time from 76.1 days in 1991 to 31.6 days in 1995, with a target of 26 days in 1996 and an overall goal of ten days (Figure 2-1). JLG improved its world-wide market share of the boom lift (61%) and the sizzor lift (118%) (Figure 2-2) during the time these changes were implemented.

Expert System - Machine Configuration

JLG Industries, Inc. developed a comprehensive software program for customer and distributor requirements entry, pricing development, supplier part requirements, in-house production part requirements, and schedule requirements to be established and phased into the production line. This system, called the Expert System Configurator, was introduced in 1992 and allows interpretation of the master bill of materials for each product manufactured according to the customer requested configuration. JLG's machine (product) order entry system was formerly a line item entry of part numbers and required special knowledge of the different models and add-on features. Manual entry was necessary when a particular model was selected, and the manufacturing order from which the machine was built had to be created. Consequently, corporate goals were established to reduce the cycle time to a goal of 10 days from the order to shipment of the machine. All redundant, non-value-added labor was to be removed from the order processing activities. A repeatable, stored configuration mechanism was required to eliminate configuration errors in the manufacturing order.

Adjustments to this system are required only when engineering modifies the available configuration with the introduction of a new prototype to the production line. The employee taking the order responds to a series of 12 high-level questions related to the general, physical characteristics of the machine being ordered. From these responses, a sales order is created for invoicing and a manufacturing order, complete with a top-level bill of materials, is introduced into the manufacturing software modules. This system resides on the AS/400 corporate computer system and a PC.

The accuracy of the bills of material was improved through the Expert System Configurator. A business growth of four to five times the number of machine orders is supported by the same number of personnel. Using this system, JLG reached the corporate goal to improve the order-to-shipment cycle time from 79 days to 30 days. Bills of material entry was reduced from the former 30-60 minutes to 3-4 minutes, and entry errors were eliminated. The ground work is being established for customer configuration entry into the system at the plant and a real-time automatic delivery quote to the customer.

Hydraulic Hose Kitting

JLG, in partnership with one of its preferred suppliers, developed and implemented a system for procuring hydraulic hose kits used in the manufacture of JLG products. Each model and product family produced by JLG have a large number of hydraulic hoses in a mix of configurations. The new hose kitting system was developed to reduce the rapidly increasing cost of maintaining, handling, processing, and accounting for the large on-hand inventory of hoses.

Previously, hoses were ordered as individual parts from MRP system requirements. Purchase orders were generated, scheduling each hose as a line item for receipt. Stocking locations containing up to a two-week supply were maintained for each hose, requiring four layers of bins occupying 2,400 square feet of space. On receipt of a shipment of hoses, receiving personnel were required to open each box and count the hoses. Transactions were manually entered into purchase receipt files using the packing slips. The hoses were then moved to the stocking location and loaded individually into the stocking bins. Shipping and packing materials for the hoses had to be crushed and discarded. Typically, 15 skids of boxes of hoses were received at a time. For each final assembly, a stockkeeper was required to pull an average of 110 hoses out of stock. At least four hours were required each evening to pull hoses for the next day's assembly requirements.

To eliminate packaging requirements, reusable carts were designed to transport hoses from the supplier located nearby directly to the workcell where they are used. Hoses are kitted by the supplier and coded with a special commodity code. As weekly machine assembly orders are released for final assembly, hydraulic hose purchase orders are automatically generated for the supplier which detail hose demand by manufacturing assembly line, workcell where needed in final assembly, and the specific machine sales order number. These are printed weekly for machines scheduled three weeks in advance and are sent to the supplier with the appropriate number of empty carts. The supplier manufactures the required hoses, sorts them, and places them in the hose carts in the same sequence as they will be used in final assembly. Hoses are delivered twice a week in time to meet assembly requirements. Purchase order receipt, issue from stock, and payments are automatically processed based on scheduled delivery. The hose carts are delivered directly to the final assembly line on receipt and empty carts are returned to receiving for shipment back to the vendor.

Since implementing this system, hose inventories have been reduced from $86K to $8K. A safety stock of critical hoses is still maintained but is continuously being reduced. Planner involvement has been reduced from six hours per week to 30 minutes. Material handling has been decreased substantially, and warehousing space has been freed for more productive use. Currently the system handles approximately 60,000 hoses per week with a total value of $50K. There has been a dramatic drop in the dollar value of hoses stocked when the system was introduced in 1994 (Figure 2-3). The dollar value of hose inventory has been steadily reduced into 1995 (Figure 2-4).

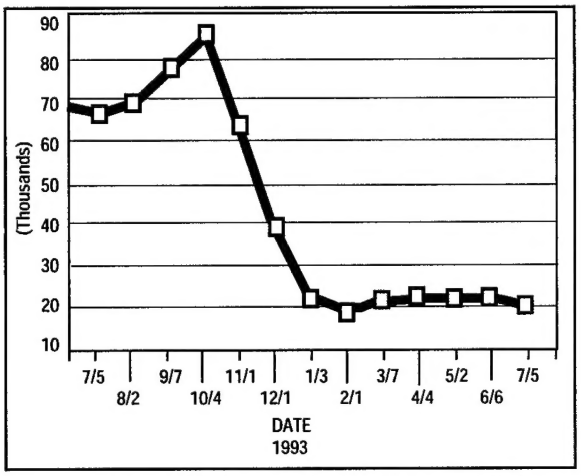


Figure 2-3. Hoses Stocked in McConnellsburg

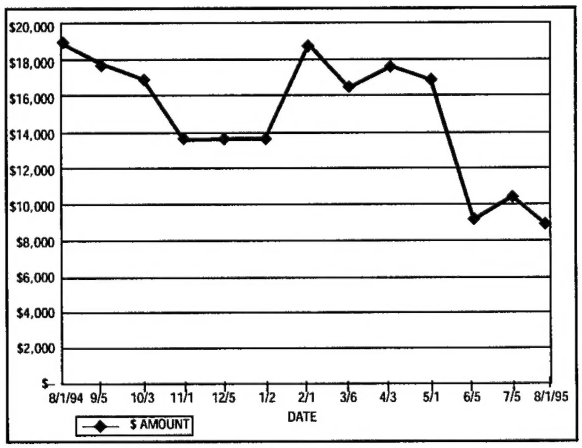


Figure 2-4. Hoses Stocked Chart

To make the system work, JLG learned that the bill of material must be very accurate and the final assembly configuration for each machine must be frozen three weeks before final assembly. The supplier was involved throughout the entire development and implementation of the process. Supplier representatives made numerous trips to JLG's plant and walked the assembly line to learn exactly how the process would work. JLG is now looking at implementing this successful approach with other suppliers. The company is also examining Electronic Data Interchange to communicate order information.

Logisitics/Management

Communication Program

In the 1990s, JLG Industries, Inc. was growing and with the required changes through the direction of the corporate strategic plan, new leadership, and rapid influx of new employees, better communications were viewed as a necessity.

As a means of addressing the communications need, JLG attempted to distribute information to the employees through GO – or Goals and Objectives – sessions in mid-1994. The initial start received a low grade. Consequently, more training was given to the individual supervisors presenting the information in the sessions, and the plant newspaper (INK) was improved through the type of information being printed by making a goal or objective the basis for a continual article. Signs were used to get current information to employees, and banners were posted to remind employees of the strategic objective. The company president and CEO held communication meetings in the manufacturing area to discuss company strategies, where company plans were taking worldwide divisions, and the present status of the company.

In April 1995, the company conducted a Benchmarking Culture and Effectiveness survey. The company received a 50% overall response, with 70% of the respondents providing additional comments. Communications were refined based on the benchmarking survey, and letters were sent to the employees with the survey results.

Quarterly celebrations are now held to celebrate company success, with lunch and a promotional item giveaway. The 1995 JLG celebration day was attended by local politicians and community leaders, and a radio station covered the event. Metrics from the Benchmarking Culture and Effectiveness survey in values, communications, performance, and obstacles will highlight the direction for improvement. The planned objectives to improve communications at JLG with an assessment directive are contained in the JLG Strategic Communications Plan.

Corrective and Preventive Action Program

JLG promotes a climate of teamwork and cooperation throughout the corporation. To meet customer demands for a high quality product at a reasonable price, JLG has focused on improving internal processes as well as communication with its suppliers. Six corrective action processes are integrated into one cohesive process that looks at internal and external processes.

Prior to initiating the ISO 9001 registration process in 1993, JLG did not have a cohesive methodology for documenting procedures. Many processes were not documented and performed only by verbal instruction. To prepare for ISO 9001 registration, JLG documented the manufacturing processes related to the requirements of the standard. For example:

1. Corrective and preventive action processes were formalized and documented.
2. Reviews and analyses of non-conforming purchased materials were certified.
3. Procedures for reviewing and analyzing customer feedback were documented.
4. Review and analysis of quality-related processes to ensure compliance to certified instructions was also established.
5. Review and analysis of the finished product (ready to ship to customer) was documented.
6. The supplier corrective action process was written.
7. A top tier procedure to unify all the corrective action procedures was developed.

Purchased materials which are defective at incoming inspection or found during the manufacturing process are entered on a Defective Material Report. Based on JLG's experience, five occurrences of the same problem in a seven-day period represents a trend which should be investigated. Fifteen or more occurrences in a 30-day period for purchased material also represents a trend. Investigation of trends is initiated using a Corrective (and Preventive) Action Request (CAR).

Customer feedback is received at JLG in several formats such as by phone, FAX, letters, and service reports. Results of the customer's inspection of equipment upon receipt are also submitted. The information is received by JLG's Customer Assurance Department and is acted on immediately as required. This information is tracked, analyzed, and forwarded to the quality engineer. He logs and examines the information to determine if any trends develop or if a potential safety issue or major system breakdown of equipment occurred in the field. In either situation, a CAR is issued to conduct a root cause analysis and determine both preventive and corrective action.

Quality product audits have been added to the corrective action process. Each customer now completes a new machine inspection report as part of the warranty registration. Product audits are performed on a random basis each month on completed machines that have been dispositioned as ready-to-ship. Any defects found are corrected and recorded. If four or more of the same defect occur on the same product line within a six-month interval, the authorized representative is notified, and reports are provided to the plant manager where the defects were found.

Quality System Audits are now performed to ensure that the JLG quality system is in accordance with the ISO 9001

requirements and that the employees are following the requirements as documented in the procedures and work instructions. Any discrepancies are documented with a CAR and a follow-up audit is conducted to verify and validate the effectiveness of the corrective action.

CARs are generated whenever a safety issue is identified, or a major product breakdown or trend is detected. It requires that the issuer check with other areas to determine if similar problems occurred in those areas. The issuer must complete the cause investigation portion after considering the standard fishbone diagram questions. JLG issues a Supplier Cause and Corrective Action Report when problems have been traced and identified to a supplier. Depending on the corrective action taken by the supplier, a visit to the facility may be required to verify the corrective action.

This comprehensive new process has helped tie corrective action processes into a cohesive set of formalized actions to eliminate the cause of problems and prevent their recurrence. The ISO 9001 process that stimulated formalization of the quality practices has already shown benefits through increased customer satisfaction, an improved rating of new machine acceptance, decreased warranty costs, and improved communication between departments.

Distributor Information System

Dealers can place service parts orders with JLG 20 hours a day using the Distributor Information System. Because many JLG customers are in foreign countries, time differences create communication problems during normal business hours. Service parts previously had to be searched for on microfiche and ordered through a service parts person.

This automated parts ordering system was established to meet rising customer needs and keep pace with demand. PC-based and on-line, interfacing directly to JLG's AS/400 computer system, the system operates in a Windows environment with a graphical user interface. The on-line access is established using a modem and telephone line applying X.25 technology (Figure 2-5). Functions include service parts order entry, service parts order inquiry, service parts item availability, service parts open item inquiry, machine "picklist" inquiry, and machine component index inquiry.

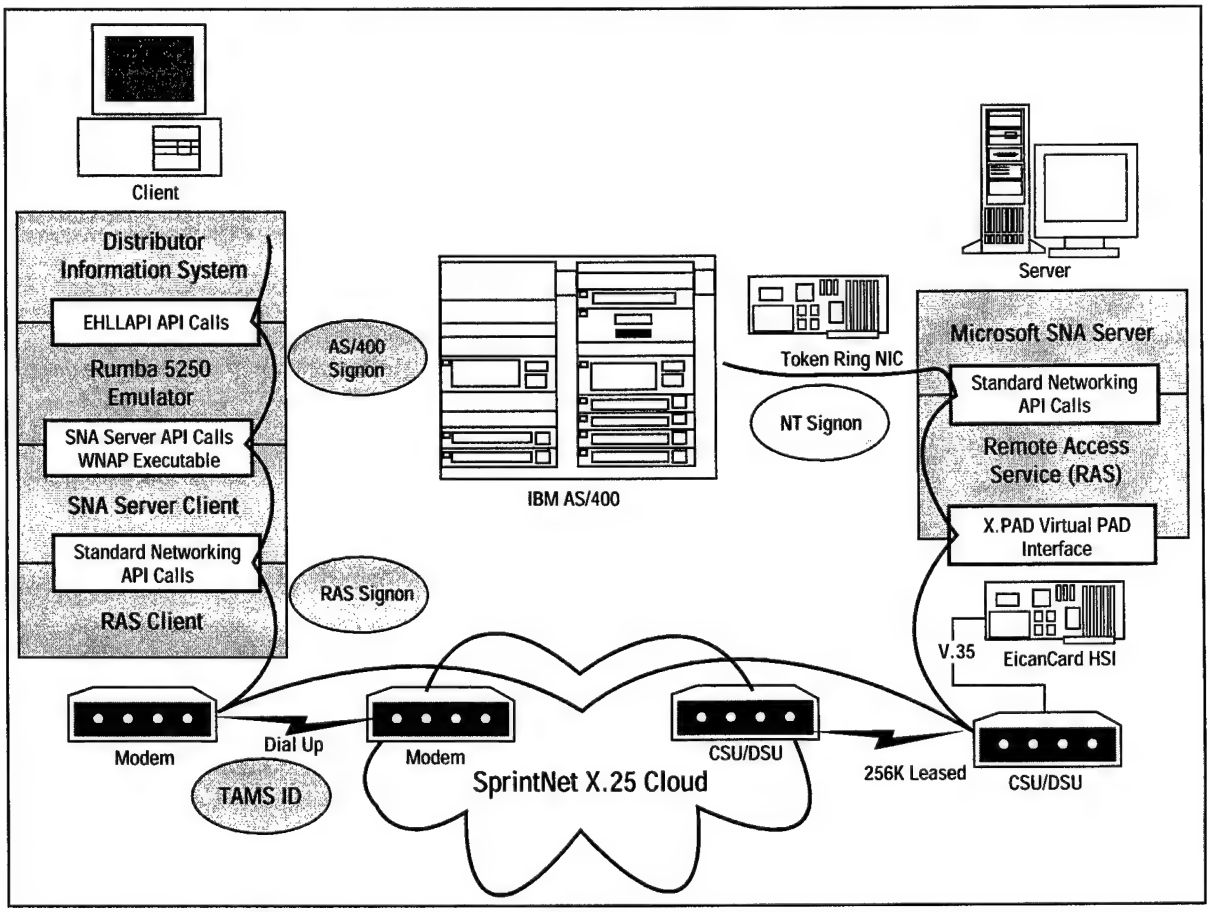


Figure 2-5. Distribution Information System Network

A unique feature of this system is its ability to list all components used to build a given serial number machine by part number in numerical sequence. (This information is available on CD-ROM for machines shipped between August 1984 and October 1995; for machines shipped after the October 1995 date, the information is available on-line. The CD-ROM disks are updated every six months.) To establish the system, JLG used a CD-ROM burner and software, installed two NT servers with EICON Cards, two MUX, and a T1 line with X.25 functionality.

To use this system, the customer needs only a PC, RUMBA software, and JLG-supplied communications software. There is a yearly subscription fee to offset JLG communications costs. Customers receive a two percent rebate on all purchases made using the system. Twenty-three customer order point locations have been established, with more than 50 scheduled to be added by February 1996. Software releases are scheduled to occur every six months. Warranty requirements and warranty claims are scheduled for the next release. Alternate communication and client-server solutions are being explored.

Benefits of the system to date include elimination of microfiche, and the ready access to accurate machine information for customers and service parts personnel, thereby reducing the number of incorrect parts ordered and shipped. The increase in lift sales will lead to further growth in lift service parts requirements within the next three years. It was estimated that the lift service parts sales staff would have to be increased by 300% in the next three years to meet the rising demand for parts. Lift service parts sales have increased by 16.9% since 1994, and lift sales have grown at a 56% rate in the same time frame. (The impact of these sales increases affect the parts area with a lag of three years.)

Rate Based Purchasing

JLG has adopted a rate-based purchasing concept that has dramatically improved the company's ability to quickly adapt its product mix and quantity in response to market changes. Prior to 1992 when the system was established, JLG maintained inventories of most of the materials required for product manufacturing, necessitating a large investment in inventory and substantial storage space. Order processing was expensive and time consuming. Production planning was inflexible because of long lead times and the need to buy in large lots to take advantage of lower prices and favorable shipping rates. As part of the conversion to rate-based purchasing, JLG focused on reducing its supplier base using a formal supplier qualification process and by developing partnerships with its major suppliers.

The system is a pipeline through which purchased materials continuously flow (Figure 2-6). Materials from a

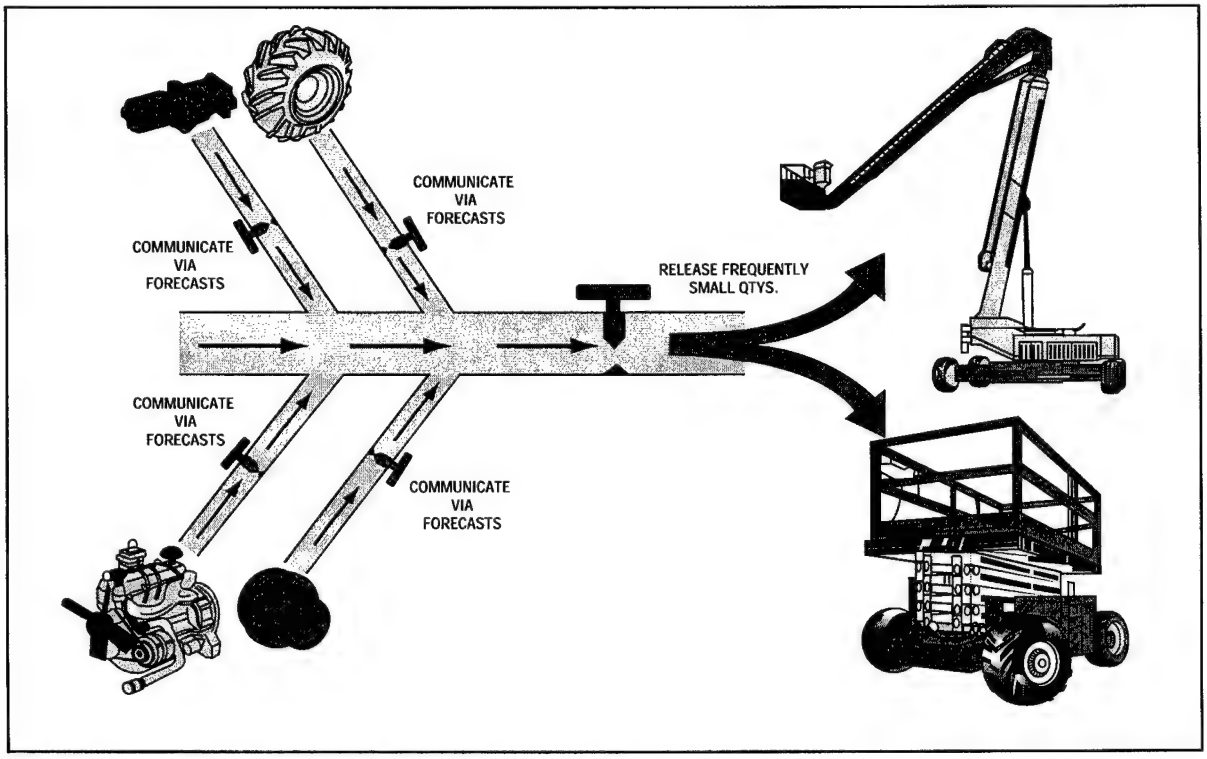


Figure 2-6. Purchased Materials Pipeline

specified vendor for each item move into the materials pipeline. Quantities are communicated through moving forecasts to each vendor who release material frequently in small quantities to feed the JIT requirements of JLG's production lines. JLG has contracted for its own express trucking services to pick up and transport the pipeline materials from vendors throughout the country. These tightly scheduled and coordinated runs give the company precise control over the flow of incoming material.

Pipeline quantities are regulated based on usage data generated by JLG's MRP system. Quantities result from the usage and replenishment time, and are specified in pipeline quantities for material on hand at JLG, finished material at the supplier's plant, and in-process material at the supplier's plant. A 52-week rolling schedule is generated by the computer and automatically FAXed to each vendor every two weeks. Releases are automatically FAXed weekly for material to be picked up on the weekly run. The materials are picked up as scheduled and delivered directly to the assembly line.

Vendor performance in meeting schedules and delivery requirements is closely tracked, as well as the performance of the trucking contractor. This information is included in quarterly supplier report cards that communicate supplier delivery and quality performance.

Currently JLG has 106 major suppliers on rate-based purchasing. Over 75% of the dollar value of purchased materials are rate based, and the company is extending the concept from production materials and parts to service parts as well. Typically, bread and butter components are expected to have long-term ongoing requirements and are thoroughly proven for their applications and for which requirements can be forecast. The supplier must be reliable with a good business relationship and a willingness to partner with JLG. Whenever possible, JLG prefers a single source for component families.

Rate-based purchasing has produced tremendous benefits for both JLG and its suppliers. JLG has reduced its inventory by more than $12M over the past three years while experiencing nearly a five-fold increase in production rates, resulting in less material handling and damage, more flexibility, and shorter response time. Annually negotiated contracts for pipeline quantities have lowered purchase commitments. Clerical work is greatly reduced by the automated computer-to-FAX ordering method. A representative example of realized savings is a diesel engine purchased from a vendor in Germany that was shipped to the plant in large lots and warehoused. In 1992, JLG maintained an average of 24 of these engines on hand. Today there are four engines on hand – a savings of $54K in inventory cost. The company saves almost $28K annually in costs for carrying, material handling, clerical transactions, and damage just for this one item. Suppliers have also benefited from rate-based purchasing in reduced inventory, better forward planning, fewer major schedule changes, less paperwork and administration, smoother business relationships, and lower costs of doing business with JLG.

ScoreCard

JLG Industries, Inc. uses an off-the-shelf commercial software package to visually depict company performance measures. JLG's ScoreCard program illustrates current trends and status of key business indicators as they apply to the corporate strategy.

ScoreCard is a visual executive information system that is also used as an indicator against a benchmark and can highlight trends. It can display up to six measures at one time including sales, returns, stock, operational, financial, and employee. The system is flexible, allowing for changes and selection of information that is useful to the company. The 26 strategic performance measures are highlighted in a stoplight (red, yellow and green) fashion. The colors represent variance indicators such as red, variance < = -10%; yellow, variance <0% and > (-10%); and green, variance > = 0%. Values are displayed in units, dollars, and percentages over periods of month-to-date or year-to-date. The software can save up to 20 user default views in the six performance categories. The Windows environment supports selection of item, date, comparative, units/dollars, and "drill down dimensions" – or sublayers within a performance category.

Strategic Planning Process

JLG's strategic plan is simple, easy to understand, fosters creative thinking, and involves the entire company. The plan – known as the Strategic Operating Plan – is a vision for the year 2000 with strategies planned for a three-year period. It presents a perspective of current conditions, patterns, trends, and market/economic conditions that may impact progress. This streamlined plan was spearheaded by the CEO of JLG to address a lack of focus on the plan after its initial establishment.

The core plan is contained on one page and highlights key issues to achieve the vision. There are three core issues to the plan and an associated initiative to address each issue. A champion (usually a department director) and a team leader (a division director) are assigned to each initiative. The team leader forms his team and develops an action plan for the assigned initiative. The team manages all efforts necessary to attain key events and goals of the action plan within the planned timeframe. The first year in the three-year plan is tracked by quarter, the second year by halves, and the third year in total. Measures are developed from the DuPont Model, and the tool for tracking the measures is a ScoreCard.

Regular tracking and review are keys to keeping the plan an active document. Simple, visual indicators provided by ScoreCard allow quick monitoring of the progress of each initiative.

This process is simple, and ownership is shared and communicated with all employees. The Strategic Planning Process is established at the home office and is being disseminated to all worldwide subdivisions of JLG Industries, Inc.

Section 3

Information

Design/Test

IPD/Product Development/Product Life Cycle

JLG modified its corporate philosophy from an engineering focus to a market-driven one in the early 1990s. The previous philosophy emphasized developing a new model and then presenting it to the sales department for marketing. Senior management has since cultivated a market-driven philosophy.

Specifications for a new machine were previously co-written by engineering and marketing personnel with little interaction until the prototype was built. After the prototype was reviewed, it was placed in the production cycle, and any remaining design issues and additional product development to meet market needs then would be addressed. This engineering-driven philosophy caused significant internal disruptions and inefficiencies in design and manufacturing due to unstable specifications. A competitive, maturing market with more knowledgeable customers helped drive JLG to make changes in the process.

JLG's market-driven approach to design and production now encompasses the entire product life cycle from initial concept through termination or replacement. The first new models developed under the new process are nearing production. Booms, scissor lifts, and personnel lifts representing all primary product types are included in these new models. The new process emphasizes corporate strategic planning. Cross-functional teams and a team-based corporate culture have also been implemented. Registration to ISO 9001 has been accomplished, and CFM has been inserted into manufacturing processes. Product quality and reliability are emphasized, and quality is now defined by the customer. The product life cycle process is consistent with the ISO 9001 procedures and has been formalized as JLG corporate policy. The product life cycle process (Figure 3-1) consists of Idea, Concept, Feasibility, Design, Development, Pre-Production, Production, Maintenance, and Termination.

Results using the new process include stable product specifications throughout the project. The process is rigorous with approval gates to proceed to the following step. Reliability testing is emphasized in the new process, and products are developed as families based on common platforms. Designs are now market- and business-driven. Although process costs are higher in the front end of the

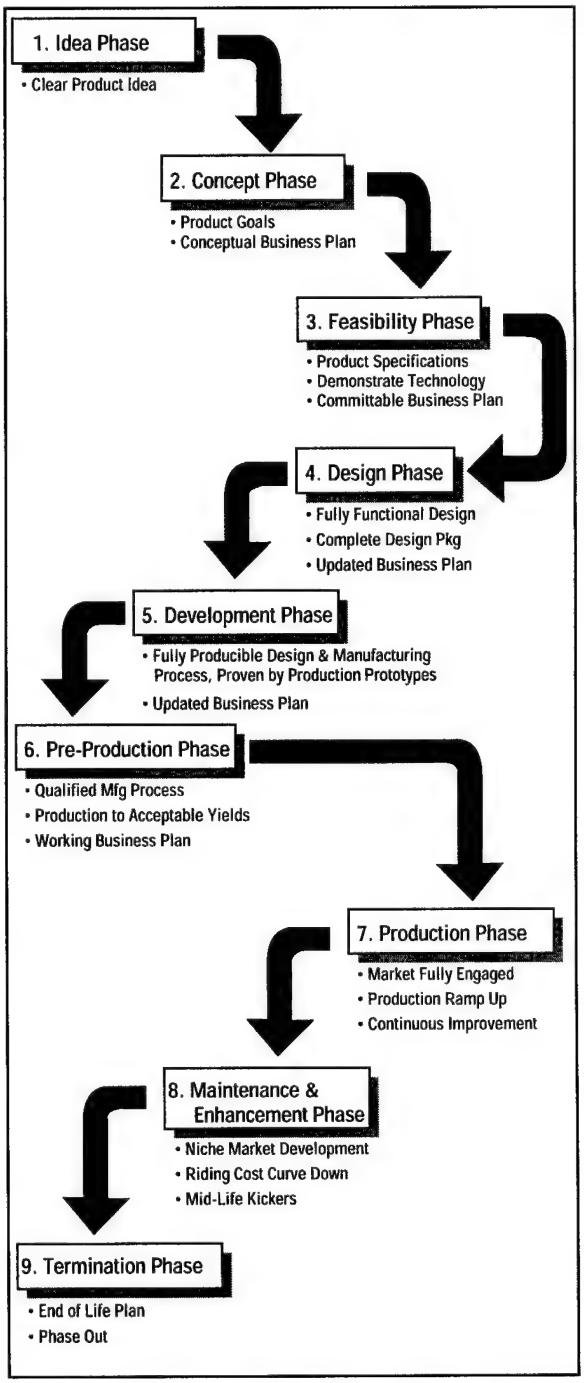


Figure 3-1. Product Life Cycle Process

process, payoffs are expected through fewer design modifications, reduced warranty costs, and fewer dissatisfied customers.

Logistics/Management

Product Safety Training

JLG has a number of effective programs to ensure that its products are properly operated and maintained. The objectives of these programs includes preventing injuries to people operating JLG products, preventing property damage, maximizing the utility and service life of the equipment, and reducing product liability exposure. The company has extensive customer product safety training programs for all of its products. These programs meet or exceed ANSI standards and are designed to prevent personal injuries and accidents resulting from improper operation of the products. They provide directions for proper procedures for equipment inspection, test, and operation. They also cover respective responsibilities of the manufacturer, dealers, owners, operators, lessors, lessees, and users.

Training programs at JLG are primarily train-the-trainer programs for distributors, although some on-site courses are conducted. The courses employ a hands-on approach and normally require from two to three days. Graduates are certified to teach safe operation of the equipment.

The Product Safety group publishes and updates manuals for each product family, and develops and produces product safety videos. Product Safety is also responsible for promulgating product safety bulletins and notices and investigating all accidents involving JLG products.

These product safety training and related programs help keep JLG products safe to operate and maintain.

Safety Compliance Program

JLG has instituted a formal policy to identify accountability for safety responsibility, and achieve management involvement at all levels of the organization. The policy defines safety program responsibilities for Supervisors, Business Unit Managers, and Plant Managers. This program, in place since May 1995, has helped the company achieve a 50% reduction in accidents.

Under this program, job descriptions include safety responsibilities and performance evaluation criteria encompass safety factors. Supervisors are responsible for providing safety orientation and periodically communicating safety information to employees. They provide monthly safety training and conduct monthly inspections and accident investigations. Business Unit Managers direct the safety programs of their units including conducting two safety inspections per year and attending one yearly meeting of the plant safety committee. Plant Managers are responsible for overall direction of their plants' safety programs.

JLG also has an aggressive program for managing and accounting for hazardous materials, considered a critical area because of the high volume of paint and other hazardous materials used. These materials require special handling and tracking to meet safety and emissions standards. The company is required by federal and state regulations to maintain a Material Safety Data Sheet for each of the hazardous materials. Currently, JLG tracks approximately 280 different materials and maintains an Material Safety Data Sheet for each. This was previously done manually but was time-consuming and prone to errors. The tracking process was automated by purchasing the software package TERMS (Corvus Software), a database management system for Material Safety Data Sheets. One benefit of this system is the ability to rapidly produce tracking reports that can be required on demand by regulatory agencies.

Skill-Based Pay Program

JLG instituted a skill-based pay (SBP) plan in 1994 to reward employees for the number of basic skills they can perform rather than for the jobs to which they are assigned. Prior to initiating this system, pay increases were based on a merit system. The merit system is still in effect; however, the SBP system focuses emphasis on continued acquisition of new skills. It also helps JLG maintain competitive pay rates with the current wage market.

The SBP program is integrated into the existing payroll system and is supported by a computerized tracking and reporting system, the Skills Management System (SMS). As an employee acquires and masters a new skill, pay is increased on a scheduled basis. Pay increases are directly proportional to employee "value" through skill acquisition. This method focuses on the individual and is a departure from the traditional concept of set pay rates for specific jobs.

Pay adjustment increments are $0.30 per hour and can be made in addition to regularly scheduled merit increases. Qualified employees are eligible to receive a skill-based wage adjustment at three specific times. The first increase is available at the completion of an initial six-month probationary employment period. An additional skill-based adjustment may be paid in conjunction with the employee's annual merit review. Other skill-based adjustments can be made yearly and six months after the annual merit review.

All hourly production workers and maintenance employees are designated in one Job Family at any specified time. A Job Family consists of a group of employees performing similar activities and requiring similar skills. Each Job Family has a set of required skills including those related to the job as well as quality and safety. Target rates are based on the degree of mastery of the complete skill set required

for a Job Family. To determine qualifications for a skill-based pay adjustment, a comparison is made between the employee's current wage rate and a target rate within the Job Family to which the employee is assigned. If the current wage rate is equal to or greater than the target range, no pay adjustment is made. If the current rate is below the target range, a skill-based adjustment will be authorized.

Skill-based assessment is an ongoing process. Formal evaluation begins at the completion of the six-month probationary period at which time the employee is tested for mastery of the minimum skills required for the Job Family; a 100% mastery rate is required for successful completion of the probationary period. After this period, the employee's progress is analyzed and training objectives are established twice a year. Careful consideration is given to the employee's interest, capabilities, limitations, and cross training requirements. Overall responsibility for skills acquisition and career development rests with the employee. The employee determines his/her level of participation in acquiring new or additional skills. Supervisors assist the process by helping the employee identify and plan for new skills to be acquired, creating opportunities for cross training, and certifying the skills training.

In place only since 1994, the program is already producing benefits. It allows supervisors and employees more flexibility in accomplishing work and managing careers. The greater skill base permits faster adaptation to changes in technology and product mix. Workers are better able to focus on problem areas and avoid idle time waiting for problems to be fixed or for work done by others. Employees can participate more actively in problem-solving and improvement activities because of a wider perspective on total work flow. The program permits lower overall staffing levels by incorporating specialized functions into team skill requirements. Workers are experiencing higher self esteem from development of personal talents and improved self managing abilities. The company has been able to raise minimum hiring qualifications. Overall increases in productivity have enabled expansion of capacity.

Skills Management System

SMS was developed to support the SBP system and the company's training and cross training programs. Prior to the SMS development in 1994, JLG did not use an automated system for tracking and reporting skills and qualifications.

SMS is a formal, automated system to help identify the specific skills for which each employee has been certified. The basic system tracks and reports the skill number, date certified, identification of trainer, how training was conducted (OJT, classroom, etc.), and when the skill expires (if applicable) for all employees. A monthly report that lists skills obtained, skills required, and comparison against the Job Family requirements is provided to each employee and his/her supervisor. The percent of skills certified within the Job Family is computed and listed on the report. This value is used for several purposes including skill-based pay determination, preference in job selection, determination of cross training objectives, and support of training objectives for use in ISO 9000 certification. It also provides managers with an overall view of training and compliance opportunities within the company.

The SMS is maintained on the corporate AS400 computer system with distributed points of entry and shop floor inquiry capability. Information about employee skills is accessible to supervisors on the shop floor reporting system. The system currently tracks 81,129 skills throughout the company.

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
BMP	Best Manufacturing Practices
CAR	Corrective Action Request
CFM	Continuous Flow Manufacturing
FMECA	Failure Mode Effect Criticality Analysis
SBP	Skill Based Pay
SMS	Skills Management System

Appendix B

BMP Survey Team

Team Member	Activity	Function
Larry Robertson (812) 854-5336	**Naval Surface Warfare Center** **Crane Division** Crane, IN	**Team Chairman**
Lisa Rogers (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Administrative Assistant**
Thomas Kirchner (317) 306-7217	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	
Rick Purcell (301) 403-8100	**BMP Center of Excellence** College Park, MD	

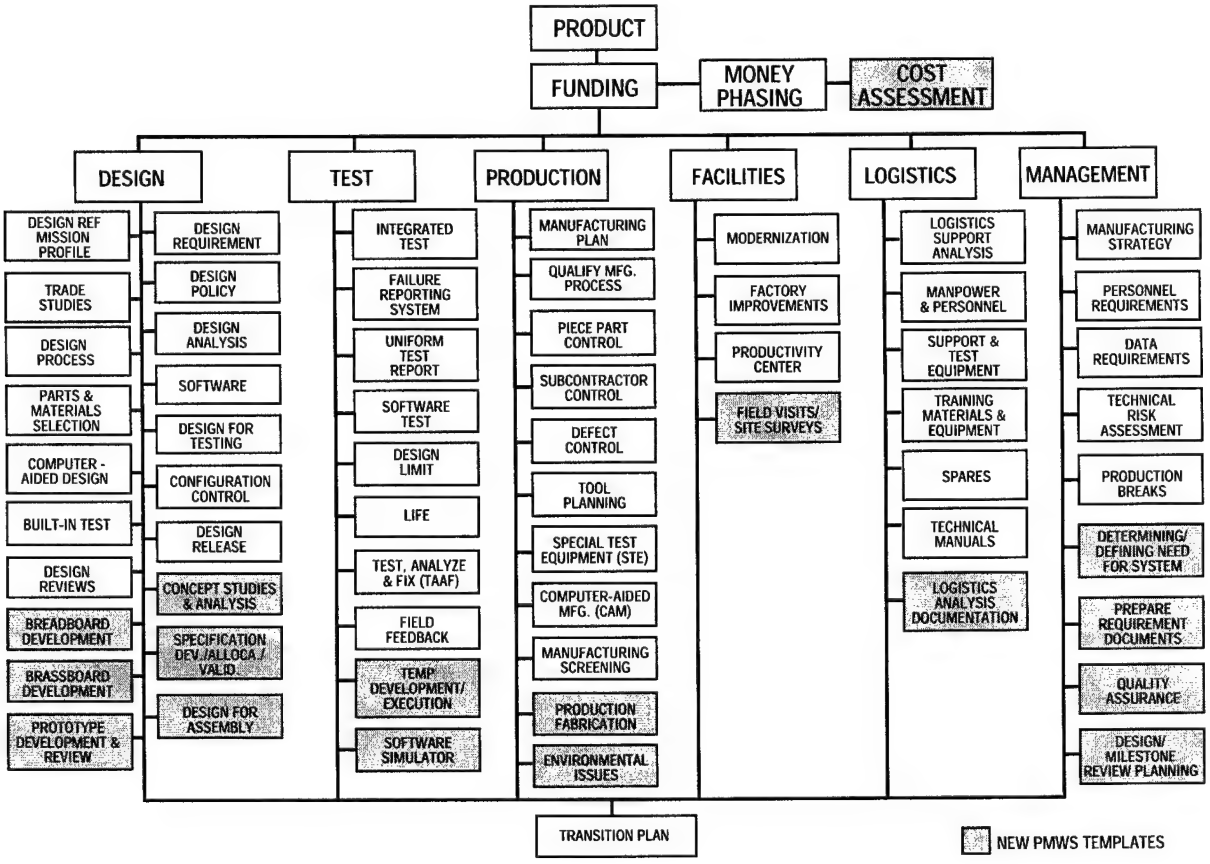
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245-7.M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"

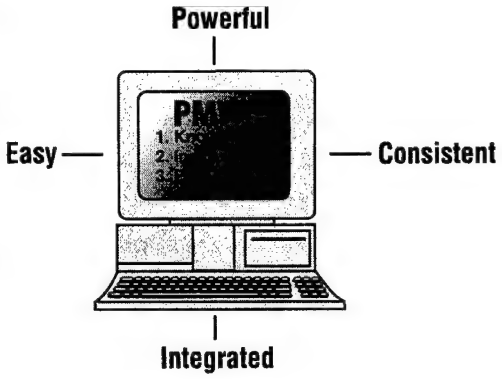


Appendix D

BMPnet and the Program Manager's Workstation

The Program Manager's Workstation (**PMWS**) is a series of interrelated software environments and knowledge-based packages that provides timely acquisition and engineering information to the user. This Workstation is hosted on the BMPnet that supports communication nationwide to promote technology transfer and continuous improvement. Access to BMPnet is through modem dial-in, free PMWS software, Internet, World Wide Web, or CD-ROM. Besides PMWS, BMPnet features include communication by electronic mail and file transfer; access to Special Interest Groups on more than 75 topics including producibility and Government specifications; information upload and download capability; and the ability to download BMPnet-resident programs.

PMWS includes **KnowHow**, an electronic library of expert technical assistance, including an intelligent search capability that gets the information users need on the screen in less than three minutes; the Technical Risk Identification and Mitigation System (**TRIMS**), a technical risk management system that may be tailored to the user's needs; the BMP database that contains over 2,000 abstracts on documented best practices; and SpecRite, a performance specification development tool.



PROGRAM MANAGER'S WORKSTATION

KnowHow is . . . Knowledge through an automated and intelligent information access system that speeds the search for required information by up to 95%. Typically, the information needed is on the screen in less than three minutes.

KnowHow features include:

- Personalized acquisition planning guidance, both high and low level, as appropriate.
- Information required for user's specific job.
- Special, logic-driven menu that allows fast access to cut research time by up to 95%.
- On-line user's manual and help.
- Application as a learning tool for new acquisition personnel.

TRIMS brings . . . Insight which identifies and ranks those program areas with the highest risk levels.

TRIMS features include:

- Ability to conduct continuous risk assessments to take pre-emptive corrective action.
- Tracking capability for key project documentation from concept through production.
- Identification function of goals, personnel, and future activities in development processes.
- Default values for many categories by program type.
- Ability to tailor all fields to suit individual program requirements.
- Reports generation.

The **BMP Database** provides . . .Information that comes directly from verified practices in industry that government experts search out looking at the best to collect answers and solutions.

BMP Database features include:

- Information on best practices in manufacturing, design, test, facilities, production, management, and logistics from 80 companies or activities.
- Ability to search for information using a natural language interface.
- Capability to print information to a file, disk or directly to a local printer.
- Phone numbers of points of contact in companies who have been surveyed.

SpecRite can help . . .Develop a performance specification generator based on expert knowledge across the services to guide acquisition personnel in creating specifications for their requirements.

SpecRite features include:

- DOS-base (runs on any PC).
- Organization and structure for the build/ approval process.
- Knowledge-based guidance and assistance.
- Flexible, modular structure.
- Output in MIL-STD 961 format and in WordPerfect 5.1 files.

To access BMPnet, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulation set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems or (703) 7267 for 9600 baud and 14.4kb. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the download of the special modem program. Then call back using this program and access all BMPnet functions. The general user account is:

USER PROFILE: BMPNET

USER ID: BMP

Password: BMPNET

If you want a personal account to receive e-mail, forward your request to Ernie Renner (BMP Program Manager) or Brian Willoughby (BMPnet Program Manager at CSC). If you encounter problems, please call (301) 403-8179.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently six Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The six BMP satellite centers include:

Corona, CA

Chris Matzke
Quality Assurance Engineer
Naval Warfare Assessment Division
Code QA-21, P. O. Box 5000
1456 Mariposa Drive
Corona, CA 91718
(909) 273-4992
fax: (909) 273-5315
internet: cmatzke@bmpcoe.org

Louisville, KY

Marshall Bramble
BMP Representative
Louisville Site, Crane Division
Naval Surface Warfare Center
5401 Southside Drive
Louisville, KY 40214
(502) 364-5272
fax: (502) 364-5272
internet: mbramble@bmpcoe.org

Oak Ridge, TN

Tammy Graham
BMP Representative
Martin Marietta Energy Systems
P. O. Box 2009, Bldg. 9737
MS 8091
Oak Ridge, TN
(615) 576-5532
fax: (615) 574-2000
internet: tgraham@bmpcoe.org

Rockford, IL

Dean Zaumseil
Mid-Western Represenative
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5530
fax: (815) 654-4459
internet: <adme3dz@rvcux1.rvc.cc.il.us>

Vallejo, CA

Jack Tamargo
West Coast Representative
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
internet address: jtamargo@bmpcoe.org

York, PA

Sherrie Snyder
Manager, Information Services
MANTEC, Inc.
P. O. Box 5046
York, PA 17405
(717) 843-5054
fax: (717) 854-0087
internet: <snyderss@mantec.org>

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
frglcc@aol.com

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
Plymouth Executive Campus
Bldg 630, Suite 100
630 West Germantown Pike
Plymouth Meeting, PA 19462
(610) 832-8800
FAX: (610) 832-8810
http://www.engriupui.edu/empf/

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

Manufacturing Science and Advanced Materials Processing Institute

The Manufacturing Science and Advanced Materials Processing Institute (MS&MPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&MPI:
Mr. Dennis Herbert
Manufacturing Science and Advanced Materials Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 11804-0030
(814) 865-8205
FAX: (814) 863-0673
dbh5@psu.edu

- **National Center for Advanced Drivetrain Technologies**
  The NCADT supports DOD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

  Point of Contact for NCADT:
  Dr. Suren Rao
  National Center for Advanced Drivetrain Technologies
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-3537
  FAX: (814) 863-1183
  http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

  The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

  Point of Contact for SEMTC:
  Surface Engineering Manufacturing Technology Center
  Dr. Maurice F. Amateau
  SEMTC/Surface Engineering Center
  P.O. Box 30
  State College, PA 16804-0030
  (814) 863-4214
  FAX: (814) 863-0006
  http://www/arl.psu.edu/divisions/arl_org.html

- **Laser Applications Research Center**

  The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

  Point of Contact for LaserARC:
  Mr. Paul Denney
  Laser Center
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-2934
  FAX: (814) 863-1183
  http://www/arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

APPENDIX G

Completed Surveys

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPNET. Requests for copies of recent survey reports or inquiries regarding the BMPNET may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 308
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
(Rockwell Defense Electronics
Collins Avionics and
Communications Division)
Cedar Rapids, IA
October 1987 and March 1995

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
(Lockheed Martin Tactical Aircraft Systems)
Fort Worth, TX
May 1988 and August 1995

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
(McDonnell-Douglas Aerospace (St. Louis))
St. Louis, MO
January 1989 and May 1995

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C^3 Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Department of Energy-
Oak Ridge Facilities
Operated by Martin Marietta Energy Systems, Inc.
Oak Ridge, TN
March 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993

McDonnell Douglas Aerospace
Huntington Beach, CA
April 1993

Crane Division
Naval Surface Warfare Center
Crane, IN and Louisville, KY
May 1993

R. J. Reynolds Tobacco Company
Winston-Salem, NC
July 1993

Hamilton Standard
Electronic Manufacturing Facility
Farmington, CT
October 1993

Harris Semiconductor
Melbourne, FL
January 1994

Naval Undersea Warfare Center
Division Keyport
Keyport, WA
May 1994

Kaiser Electronics
San Jose, CA
July 1994

Stafford County Public Schools
Stafford County, VA
July 1994

Lockheed Martin
Electronics & Missiles
Orlando, FL
April 1995

Wainwright Industries
St. Peters, MO
June 1995

JLG Laboratories, Inc.
York, PA
November 1995

Philadelphia Naval Shipyard
Philadelphia, PA
June 1993

Crystal Gateway Marriott Hotel
Arlington, VA
August 1993

Alpha Industries, Inc
Methuen, MA
November 1993

United Defense, L.P.
Ground Systems Division
San Jose, CA
March 1994

Mason & Hanger
Silas Mason Co., Inc.
Middletown, IA
July 1994

U.S. Army
Combat Systems Test Activity
Aberdeen, MD
August 1994

Sandia National Laboratories
Albuquerque, NM
January 1995

Dayton Parts, Inc.
Harrisburg, PA
June 1995

Sacramento Manufacturing and Services Division
Sacramento, CA
October 1995

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